

Understanding IP Addressing: Everything You Ever Wanted To Know

Background

The Internet continues to grow at a phenomenal rate. This is reflected in the tremendous popularity of the World Wide Web (WWW), the opportunities that businesses see in reaching customers from virtual storefronts, and the emergence of new ways of doing business. It is clear that expanding business and public awareness will continue to increase demand for access to resources on the Internet.

Internet Scaling Problems

Over the past few years, the Internet has experienced two major scaling issues as it has struggled to provide continuous and uninterrupted growth:

- The eventual exhaustion of IP version 4 (IPv4) address space
- The need to route traffic between the ever increasing number of networks that comprise the Internet

The first problem is concerned with the eventual depletion of the IP address space. IPv4 defines a 32-bit address which means that there are only 2^{32} (4,294,967,296) IPv4 addresses available. As the Internet continues to grow, this finite number of IP addresses will eventually be exhausted.

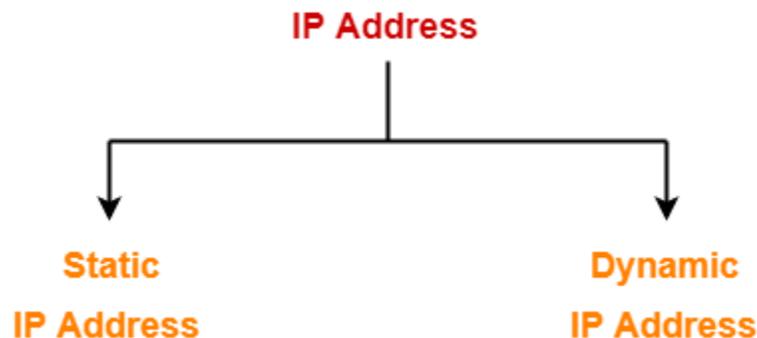
The address shortage problem is aggravated by the fact that portions of the IP address space have not been efficiently allocated. Also, the traditional model of classful addressing does not allow the address space to be used to its maximum potential. The Address Lifetime Expectancy (ALE) Working Group of the Internet Engineering Task Force (IETF) has expressed concerns that if the current address allocation policies are not modified, the Internet will experience a near to medium term exhaustion of its unallocated address pool. If the Internet's address supply problem is not solved, new users may be unable to connect to the global Internet. More than half of all possible IPv4 addresses have been assigned to ISPs, corporations, and government agencies, but only an estimated 69 million addresses are actually in use.

About IP Addressing

- IP Address is short for **Internet Protocol Address**.
- It is a unique address assigned to each computing device in an IP network.
- ISP assigns IP Address to all the devices present on its network.
- Computing devices use IP Address to identify and communicate with other devices in the IP network.

Types Of IP Address-

IP Addresses may be of the following two types-



1. Static IP Address-

- Static IP Address is an IP Address that once assigned to a network element always remains the same.
- They are configured manually.
- Some ISPs do not provide static IP addresses.
- Static IP Addresses are more costly than dynamic IP Addresses

2. Dynamic IP Address-

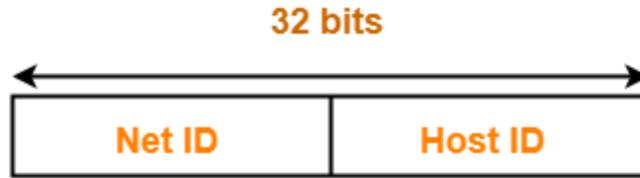
Dynamic IP Address is a temporarily assigned IP Address to a network element.

- It can be assigned to a different device if it is not in use.
- DHCP or PPPoE assigns dynamic IP addresses.

IP Address Format-

IP Address is a 32 bit binary address written as 4 numbers separated by dots.

- The 4 numbers are called as **octets** where each octet has 8 bits.
- The octets are divided into 2 components- Net ID and Host ID.



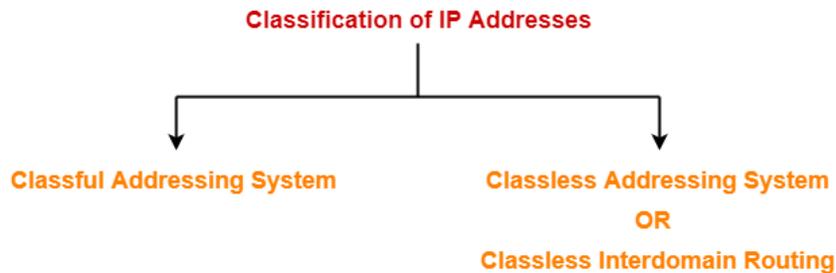
Format of an IP Address

1. **Network ID** represents the IP Address of the network and is used to identify the network.
2. **Host ID** represents the IP Address of the host and is used to identify the host within the network.

IP Address Example-

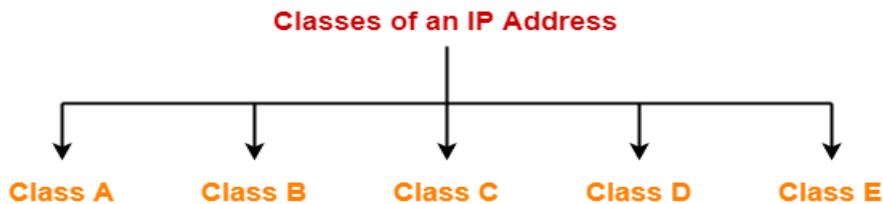
Example of an IP Address is-
 00000001.10100000.00001010.11110000
 (Binary Representation)
OR
 1.160.10.240
 (Decimal Representation)

There are two systems in which IP Addresses are classified-



Classful Addressing

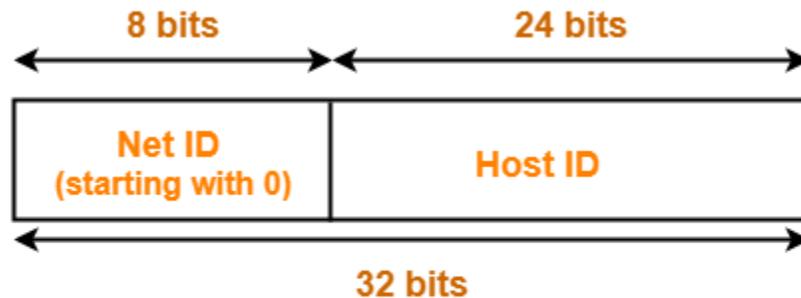
In Classful Addressing System, IP Addresses are organized into following 5 classes-



1. Class A- If the 32 bit binary address starts with a bit 0, then IP Address belongs to class A.

In class A IP Address,

- The first 8 bits are used for the Network ID.
- The remaining 24 bits are used for the Host ID.



Class A IP Address

Total Number Of IP Addresses-

Total number of IP Addresses available in class A

= Numbers possible due to remaining available 31 bits = 2^{31}

Total Number Of Networks-

Total number of networks available in class A

= Numbers possible due to remaining available 7 bits in the Net ID – 2

= $2^7 - 2 = 126$

Total Number Of Hosts-

Total number of hosts that can be configured in class A

= Numbers possible due to available 24 bits in the Host ID – 2 = $2^{24} - 2$

(The reason of subtracting 2 is explained later.)

Range Of 1st Octet- We have-

- Minimum value of 1st octet = 00000000 = 0
- Maximum value of 1st octet = 01111111 = 127

From here,

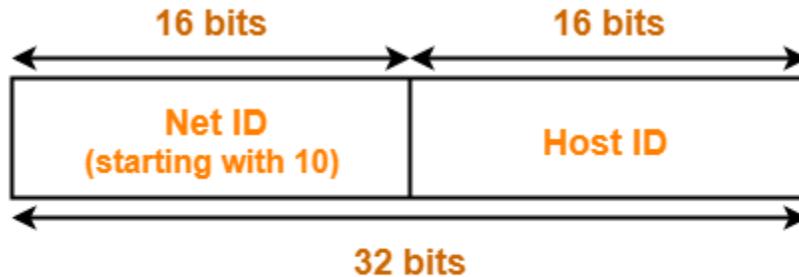
- Range of 1st octet = [0, 127]
- But 2 networks are reserved and unused.
- So, Range of 1st octet = [1, 126]

Use- Class A is used by organizations requiring very large size networks like NASA, Pentagon etc.

2. Class B- If the 32 bit binary address starts with bits 10, then IP Address belongs to class B.

In class B IP Address,

- The first 16 bits are used for the Network ID.
- The remaining 16 bits are used for the Host ID.



Class B IP Address

Total Number Of IP Addresses-

Total number of IP Addresses available in class B

= Numbers possible due to remaining available 30 bits = 2^{30}

Total Number Of Networks-

Total number of networks available in class B

= Numbers possible due to remaining available 14 bits in the Net ID = 2^{14}

Total Number Of Hosts-

Total number of hosts that can be configured in class B

= Numbers possible due to available 16 bits in the Host ID - 2 = $2^{16} - 2$

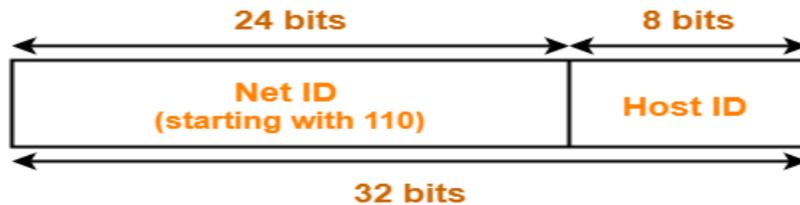
Range Of 1st Octet- We have-

- Minimum value of 1st octet = **10000000** = 128
 - Maximum value of 1st octet = **10111111** = 191
- So, Range of 1st octet = [128, 191]

Use- Class B is used by organizations requiring medium size networks like IRCTC, banks etc.

3. Class C- If the 32 bit binary address starts with bits 110, then IP Address belongs to class C. In class C IP Address,

- The first 24 bits are used for the Network ID.
- The remaining 8 bits are used for the Host ID.



Class C IP Address

Total Number Of IP Addresses-

Total number of IP Addresses available in class C
 = Numbers possible due to remaining available 29 bits = 2^{29}

Total Number Of Networks-

Total number of networks available in class C
 = Numbers possible due to remaining available 21 bits in the Net ID = 2^{21}

Total Number Of Hosts-

Total number of hosts that can be configured in class C
 = Numbers possible due to available 8 bits in the Host ID – 2 = $2^8 - 2$

Range Of 1st Octet-We have-

- Minimum value of 1st octet = **11000000** = 192
 - Maximum value of 1st octet = **11011111** = 223
- So, Range of 1st octet = [192, 223]

Use-Class C is used by organizations requiring small to medium size networks.

- For example- engineering colleges, small universities, small offices etc.

4. Class D- If the 32 bit binary address starts with bits 1110, then IP Address belongs to class D.

- Class D is not divided into Network ID and Host ID.



Class D IP Address

Total Number Of IP Addresses-

Total number of IP Addresses available in class D

= Numbers possible due to remaining available 28 bits = 2^{28}

Range Of 1st Octet We have-

- Minimum value of 1st octet = **11100000** = 224
- Maximum value of 1st octet = **11101111** = 239

So, Range of 1st octet = [224, 239]

Use-

- Class D is reserved for multicasting.
- In multicasting, there is no need to extract host address from the IP Address.
- This is because data is not destined for a particular host.

5. Class E- If the 32 bit binary address starts with bits 1111, then IP Address belongs to class E

Class E is not divided into Network ID and Host ID.



Total Number Of IP Addresses-

Total number of IP Addresses available in class E
= Numbers possible due to remaining available 28 bits = 2^{28}

Range Of 1st Octet-We have-

- Minimum value of 1st octet = **11110000** = 240
- Maximum value of 1st octet = **11111111** = 255

So, Range of 1st octet = [240, 255]

Use- Class E is reserved for future or experimental purposes.

Rules for assigning Host ID:

The Host ID is used to determine the host within any network. The Host ID is assigned based on the following rules:

- The Host ID must be unique within any network.

- The Host ID in which all the bits are set to 0 cannot be assigned as it is used to represent the network ID of the IP address.
- The Host ID in which all the bits are set to 1 cannot be assigned as it is reserved for the multicast address.

Rules for assigning Network ID:

If the hosts are located within the same local network, then they are assigned with the same network ID. The following are the rules for assigning Network ID:

- The network ID cannot start with 127 as 127 is used by Class A.
- The Network ID in which all the bits are set to 0 cannot be assigned as it is used to specify a particular host on the local network.
- The Network ID in which all the bits are set to 1 cannot be assigned as it is reserved for the multicast address.

Classes of IP Address- All the classes of IP Address are summarized in the following table-

Class of IP Address	Total Number of IP Addresses	1st Octet Decimal Range	Number of Networks available	Hosts per network	Default Subnet Mask
Class A	2^{31}	1 – 126	$2^7 - 2$	$2^{24} - 2$	255.0.0.0
Class B	2^{30}	128 – 191	2^{14}	$2^{16} - 2$	255.255.0.0
Class C	2^{29}	192 – 223	2^{21}	$2^8 - 2$	255.255.255.0
Class D	2^{28}	224 – 239	Not defined	Not defined	Not defined
Class E	2^{28}	240 – 254	Not defined	Not defined	Not defined

Classless Addressing

Classless Addressing is an improved IP Addressing system.

- It makes the allocation of IP Addresses more efficient.
- It replaces the older classful addressing system based on classes.
- It is also known as **Classless Inter Domain Routing (CIDR)**.

CIDR Block-

When a user asks for specific number of IP Addresses,

- CIDR dynamically assigns a block of IP Addresses based on certain rules.
- This block contains the required number of IP Addresses as demanded by the user.
- This block of IP Addresses is called as a **CIDR block**.

Rules For Creating CIDR Block- A CIDR block is created based on the following 3 rules-

Rule-01: All the IP Addresses in the CIDR block must be contiguous.

Rule-02:

- The size of the block must be presentable as power of 2.
- Size of the block is the total number of IP Addresses contained in the block.
- Size of any CIDR block will always be in the form $2^1, 2^2, 2^3, 2^4, 2^5$ and so on.

Rule-03: First IP Address of the block must be divisible by the size of the block.

REMEMBER

If any binary pattern consisting of $(m + n)$ bits is divided by 2^n , then-

- Remainder is least significant n bits
- Quotient is most significant m bits

So, any binary pattern is divisible by 2^n , if and only if its least significant n bits are 0.

Examples-

Consider a binary pattern-

01100100.00000001.00000010.01000000

(represented as 100.1.2.64)

- It is divisible by 2^5 since its least significant 5 bits are zero.
- It is divisible by 2^6 since its least significant 6 bits are zero.
- It is not divisible by 2^7 since its least significant 7 bits are not zero.

CIDR Notation-

CIDR IP Addresses look like- **a.b.c.d / n**

They end with a slash followed by a number called as IP network prefix.

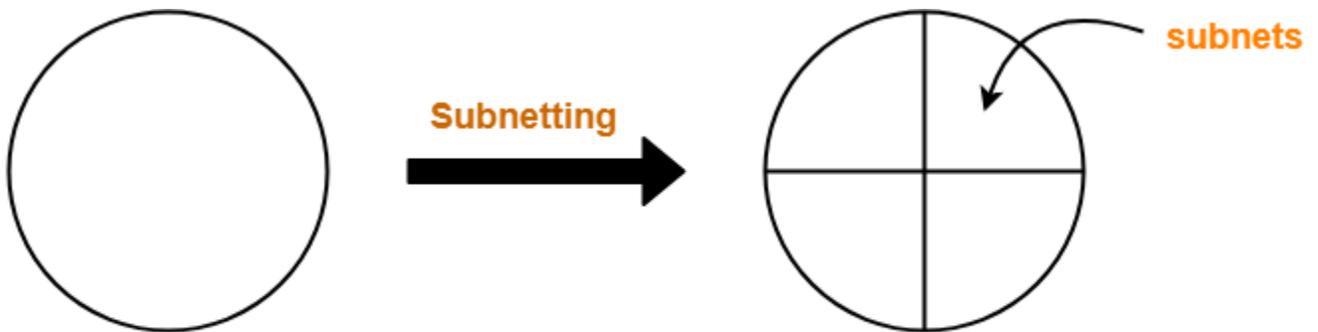
- IP network prefix tells the number of bits used for the identification of network.
- Remaining bits are used for the identification of hosts in the network.

Subnetting in Networking-

In networking,

- The process of dividing a single network into multiple sub networks is called as **subnetting**.
- The sub networks so created are called as **subnets**.

Example-Following diagram shows the subnetting of a big single network into 4 smaller subnets-



Big Single Network

Division of network into 4 subnets

Advantages- The two main advantages of subnetting a network are-

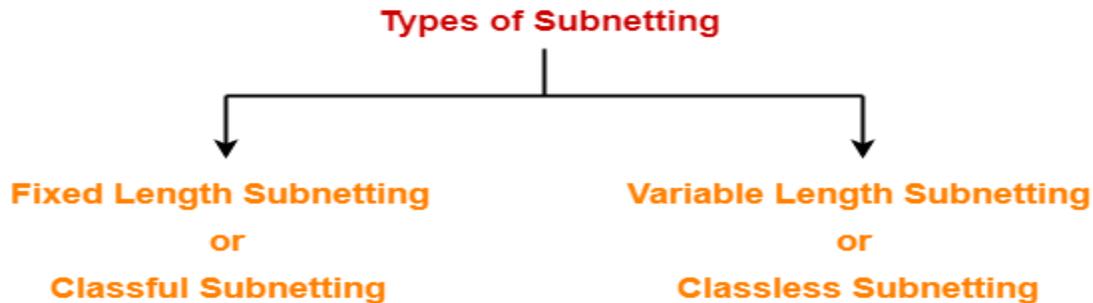
- It improves the security.
- The maintenance and administration of subnets is easy.

Subnet ID-Each subnet has its unique network address known as its **Subnet ID**.

- The subnet ID is created by borrowing some bits from the Host ID part of the IP Address.
- The number of bits borrowed depends on the number of subnets created.

Types of Subnetting-

Subnetting of a network may be carried out in the following two ways-



1. Fixed Length Subnetting- Fixed length subnetting also called as **classful subnetting** divides the network into subnets where-

- All the subnets are of same size.
- All the subnets have equal number of hosts.
- All the subnets have same subnet mask.

2. Variable Length Subnetting- Variable length subnetting also called as **classless subnetting** divides the network into subnets where-

- All the subnets are not of same size.
- All the subnets do not have equal number of hosts.
- All the subnets do not have same subnet mask.

Disadvantages of Subnetting-

1. Subnetting leads to loss of IP Addresses.

During subnetting,

- We have to face a loss of IP Addresses.
- This is because two IP Addresses are wasted for each subnet.
- One IP address is wasted for its network address.
- Other IP Address is wasted for its direct broadcasting address.

2. Subnetting leads to complicated communication process

After subnetting, the communication process becomes complex involving the following 4 steps-

1. Identifying the network

2. Identifying the sub network
3. Identifying the host
4. Identifying the process

Subnet Mask Use- Subnet mask is used to determine to which network the given IP Address belongs to. Host use its subnet mask to determine whether the other host it wants to communicate with is present within the same network or not.

- If the destination host is present within the same network, then source host sends the packet directly to the destination host.
- If the destination host is present in some other network, then source host routes the packet to the default gateway (router).
- Router then sends the packet to the destination host.